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ANALYTIC
R E V I E W

Contemporary Approaches to Prescribing Exercise in Coronary Artery Disease Patients

Abstract: Health care professionals engaged in the management of coronary artery disease (CAD) patients, both in primary and secondary prevention settings, should possess the knowledge to develop and modify both aerobic exercise as well as musculoskeletal resistance exercise training programs. The traditional exercise prescription (ExRx) for aerobic-type exercise describes the intensity, frequency, duration, and mode of exercise, as well as the rate of progression. The more contemporary ExRx focuses on the energy expenditure associated with all physical activity not just structured exercise bouts. The total “volume or dose” of physical activity is associated with important health outcomes, including the potential to prevent and potentially reverse CAD lesions. Also, emerging evidence supporting the use of high-intensity interval training in CAD patients will also be provided. Furthermore, this review will also address the issue of generating an appropriate ExRx in the absence of maximal exercise “stress” test data, a common occurrence in

the primary care setting and in this era of health care cost containment. Prescribing resistance exercise for CAD patients requires careful consideration and will be discussed in this review. Finally, this review will conclude with a section that describes the special considerations and/or modifications for some common comorbidities seen in CAD patients

chronic disease risk factors, behavioral readiness for change, personal goals, exercise preferences, as well as schedule considerations. The purpose of an individualized ExRx is to (a) enhance one or more facets of physical fitness (eg, aerobic endurance, muscular strength/endurance), (b) promote health by modification of chronic disease risk factors (eg, decrease excess body fat,

The optimal exercise prescription (ExRx) should take into account an individual's health status, chronic disease risk factors, . . .

Keywords: coronary regression; fitness; exercise training; weight training; oxygen consumption

The optimal exercise prescription (ExRx) should take into account an individual's health status,

normalize blood lipids or blood pressure [BP]), and (c) ensure safety during exercise participation (ie, decrease incidence of cardiovascular complications and/or musculoskeletal injuries).¹ The American College of Sports Medicine (ACSM),² the American Association of Cardiovascular and

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Table 1.

Elements of the Aerobic Exercise Prescription.

Variable	Recommendation
Mode	Aerobic: rhythmical and continuous in nature
Intensity	55%/65% to 90% maximal HR
	40%/50% to 85% maximal VO_2R or HR reserve
Frequency	Three to 5 sessions per week
Duration	20-60 minutes of continuous or intermittent aerobic activity
Progression	Individualized based on tolerance and adaptation; maintenance programs should include energy expenditure threshold of >1500 kcal/week

Abbreviations: HR, heart rate; VO_2R , oxygen uptake reserve.

Pulmonary Rehabilitation (AACVPR),³ and American Heart Association^{4,5} each have published guidelines for coronary artery disease (CAD) patients participating in preventive and rehabilitative exercise programs, and these guidelines should be reviewed by health care providers providing exercise recommendations and serve as the basis for many of the recommendations contained in this review.

Cardiorespiratory “Aerobic” Exercise Training

The cornerstone of a cardiovascular disease prevention and rehabilitative exercise programs is the aerobic (ie, cardiorespiratory or “cardio”) exercise training (AE) component, as this type of exercise provides many important health benefits. As seen in Table 1 and discussed below, the traditional approach for prescribing AE describes the following components: mode, intensity, duration, frequency, and progression.

Mode of Aerobic Exercise Training

Aerobic-type exercise includes a variety of physical activities that require the use of oxidative aerobic energy pathways and uses large-muscle groups continuously and rhythmically.

Traditionally, activities such as walking, jogging, cycling, swimming, cross-country skiing, and aerobic dancing are the primary modes for AE.² Moreover, a variety of indoor exercise machines, such as stair climbers, upright and recumbent leg cycles, and elliptical trainers, and the like, are appropriate and quite popular. Perhaps the most important consideration in choosing the mode of exercise for a given patient is their level of enjoyment and comfort. If a patient does not enjoy, or at least tolerate, a particular mode of exercise, it is unlikely that they will maintain sufficient compliance to this mode of exercise over time. Moreover, variation of the exercise mode is important to prevent boredom as well as overuse injuries.

Intensity of Aerobic Exercise Training

Guidelines for defining the appropriate AE intensity for patients in primary and secondary prevention programs vary based on the patients' risk (low, moderate, or high) for exercise complications.³ While the general guidelines for prescribing exercise intensity apply to most patients, the risks associated with exercise training are greater for those with a history of CAD.⁶ For patients with normal responses to graded exercise (eg, normal “stress” tests), the appropriate AE exercise

intensity can be based on a percentage of maximal heart rate reserve (MHRR) or percentage of maximal oxygen consumption reserve (VO_2R).^{7,8} For CAD patients who have normal electrocardiogram (ECG) and hemodynamic responses to graded exercise, the ACSM guidelines² indicate that a minimal-intensity threshold lies between 40% and 50% of a patient's MHRR or VO_2R , with the upper end of the intensity range being approximately 85%. Once the relative intensity is defined (% VO_2R), a target VO_2 and/or heart rate (HR) range can be calculated.

However, for patients who have exercise-induced signs or symptoms (such as angina, ST segment changes on ECG, hypotension, arrhythmia), the AE exercise training intensity needs to be set below the abnormal response in order to provide a safety buffer during AE.² Table 2 provides a list of abnormal signs and symptoms for which an upper limit for exercise intensity should be set, regardless of the calculated MHRR or VO_2R . In such cases, the AE intensity should be set at least 10 bpm below the exercise HR associated with any of the signs or symptoms listed in Table 2.² In addition, careful monitoring of the patient's symptoms, HR, BP, and ECG is recommended to ensure that the intensity of exercise remains at a safe level. Another method for determining

Table 2.

Signs and Symptoms for Which an Upper Limit for Exercise Intensity Should Be Set.

Onset of angina or other symptoms of CV insufficiency
Plateau or decrease in SBP, SBP >240 mm Hg, or DBP >110 mm Hg
1 mm ST depression, horizontal or downsloping
Radionuclide evidence of LV dysfunction or onset of moderate to severe wall motion abnormalities during exertion
Increased frequency of ventricular arrhythmias
Other significant ECG disturbances (eg, second- or third-degree AV block, atrial fibrillation, supraventricular tachycardia, complex ventricular ectopy)
Other signs or symptoms or intolerance to exercise

Abbreviations: CV, cardiovascular; SBP, systolic blood pressure; DBP, diastolic blood pressure; LV, left ventricular; ECG, electrocardiogram.

AE intensity involves a shift from a “range-based” approach to a “threshold-based” prescription based on data obtained by an incremental exercise test.⁸

Most of the medications used to control BP and cardiac arrhythmias do not affect exercise tolerance and have minimal impact on HR and myocardial contractility. However, β -blockers and some calcium channel blockers (ie, diltiazem and verapamil) will likely decrease HR at rest and during exercise.⁹ Consequently, HR ranges calculated to guide AE exercise intensity should be based on exercise test data obtained while patients are taking their standard regimen of medications. If the patient did not take his or her medication before the exercise test (commonly done for “diagnostic” stress tests) or when medication dosage changes, one option is to conduct an submaximal exercise “evaluation” (on a bike or treadmill) where the patient exercises for several minutes at approximately 40% and 80% of their VO_2 peak. HRs obtained at these intensity levels should provide the appropriate AE intensity.¹

In addition to objective measures of HR and/or VO_2 R, ratings of perceived exertion (RPEs) may be used as an adjunct to guide AE exercise intensity in patients with CAD.¹⁻³ The 15-point (6-20) RPE scale^{10,11} is typically used for this

purpose with RPE values of 11 to 13 being recommended for the early exercise sessions, whereas a range of 12 to 15 is recommended for the higher training intensities during subsequent exercise training sessions.^{2,3} Use of such generalized RPE ranges for monitoring training intensity, such as those reflected earlier, is based on the assumption that a number on the RPE scale equates to a relative physiological intensity (% MHR or VO_2 R).² However, within a given patient, specific RPE values do not always match with the relative physiological intensity during AE, especially when attempting to translate RPEs from the exercise testing to the exercise training environment.^{12,13} To use RPEs effectively for guiding the AE intensity in prevention and rehabilitation settings, the following are recommended¹²:

- The RPE scale should be described providing explanations of the resting and maximal numbers (6-20, respectively) and reviewing the descriptors assigned to each number on the scale.
- Monitoring takes place in a discreet manner to avoid influence by ratings of other patients exercising in the same area.
- Once the patient reaches a steady-state level during exercise, have the

individual rate his or her perceived exertion using the RPE scale. If, over the course of several exercise sessions, the patient reports a consistent RPE at the same physiological intensity, that RPE may be used, in conjunction with physiological markers, for monitoring the patient's training intensity.

- If the patient's RPEs vary considerably from day to day (at the same physiological intensity) after adequate acclimation, perceived exertion may not be an appropriate means for monitoring physiological intensity for this patient.

Prescribing Aerobic Exercise Training Intensity Without Exercise “Stress” Test Data

The use of MHR and/or VO_2 to prescribe the AE intensity requires access to data obtained from an exercise “stress” test, preferably one with a “maximal” or “sign/symptom-limited” endpoint. However, a survey¹³ indicated that a majority of CAD patients do not perform an exercise stress test prior to initiating an Phase II Cardiac Rehabilitation program. Consequently, in lieu of “objective” exercise test data, such as HR and VO_2 , the ExRx must be generated through other less objective methods. It has been well established that calculating exercise HR ranges based on

Figure 1.

Average and individual % VO_2R of cardiac rehabilitation participants when exercising at HR + 20 or RPE 11 to 13.

age-predicting maximal HR equations (ie, $220 - \text{age}$) is inappropriate for CAD patients, particularly those on β -blockers.^{14,15} However, there are several “evidence-based” options^{2,3} for prescribing exercise without exercise test data, including use of RPEs (as described earlier), resting HR plus an arbitrary value (generally 20 bpm for post-myocardial infarction [MI] or post-coronary artery bypass graft [CABG] patients on β -blockers or 30 bpm for non- β -blocked patients), or data from the “talk test”^{16,17} to regulate the AE exercise intensity in secondary prevention settings. The “talk test” reflects the highest level of exercise that can be maintained while still being able to hold a normal conversation that correlates well with the ventilatory threshold.^{16,17} Another approach is to perform a submaximal exercise assessment or conduct a 6-minute walk test during one of the first outpatient exercise sessions and use HR and MET levels derived from these tests as target intensities for early AE sessions.¹

Joo et al¹⁸ evaluated the common practice of regulating AE intensity using RPE as well as resting HR + 20 bpm in a group of CAD patients entering an outpatient cardiac rehabilitation program. After 2 introductory/familiarity exercise sessions, patients wore a portable

ambulatory oxygen uptake analyzer while performing 10 minutes of continuous track walking at 2 different (and randomly ordered) exercise intensity levels: RPE levels of 11 to 13 and rest HR + 20 bpm (or for non- β -blocked patients). We demonstrated that prescribing AE exercise, based on RPE and resting HR + 20/30 bpm, resulted in an average VO_2R of 42% and 71%, respectively, in cardiac rehabilitation participants (Figure 1). While the *average* exercise intensity from both techniques was at appropriate levels (Figure 1), using HR + 20/30 bpm, individual patients often exercised at a significantly lower ($\leq 40\%$ of VO_2R) intensity level whereas using RPE 11 to 12 individual patients commonly exercised at significantly higher ($\geq 90\%$ of VO_2R) intensity levels. These findings suggest that prescribing AE exercise using RPE and rest HR + 20/30 bpm results in a significant amount of intersubject variability (Figure 1) and that caution should be used when guiding AE exercise intensity with either of these approaches. Brawner et al¹⁵ demonstrated that the AE intensity calculated from resting HR + 20 bpm corresponded with a relatively low 45% and 31% of MHRR of β -blocked and non- β -blocked CAD patients, respectively.

Pharmacologic “stress” tests are commonly conducted in CAD patients whose inability to exercise adequately (due to neurological, vascular, or orthopedic) may compromise the predictive accuracy of the test.² Pharmacologic stress tests involve the infusion of medications that either increase myocardial demand (dobutamine) or reduce myocardial supply (dipyridamole, adenosine, or regadenoson) by vasodilating nonoccluded coronary arteries (eg, coronary “steal”) to induce myocardial ischemia with concomitant echocardiography or myocardial perfusion imaging, respectively. Although pharmacologic testing with these imaging approaches increase the sensitivity and specificity for myocardial ischemia compared to ECG stress tests, they do not provide an assessment of functional capacity, hemodynamic responses to progressive exercise, or an indication of the ischemic “threshold.” Consequently, data from these tests are of little value in the determination of the appropriate AE intensity. Thus, if the pharmacologic stress test is negative for ischemic abnormalities and symptoms, the highest HR obtained during the stress test can be used to guide the initial AE intensity. However, data obtained from a positive pharmacologic test will be more difficult to use for ExRx since it will not be possible to determine the level of exertion where ischemic abnormalities begin to occur. Consequently, for patients with positive “pharmacologic” stress tests, it will be necessary to cautiously use other complimentary methods (eg, signs/symptoms and/or perceived exertion) to guide the AE intensity in their exercise sessions. These patients should be carefully monitored during AE to prevent untoward events.

One study¹⁹ compared the rehabilitation outcomes of 229 post-MI and post-CABG participants that had undergone preliminary symptom-limited exercise testing with 271 matched patients who do not. All participants underwent a 12-week exercise-based cardiac rehabilitation program (including

ECG-telemetry monitoring for first 3-6 weeks). The group without a preliminary exercise test started at exercise levels of 2 to 3 METs and progressed using HR and perceived exertion. Both groups showed similar physiologic improvements over the 12 weeks, and no complications were observed in either group. This study suggests that well-managed and stable CAD patients, even without preliminary exercise test data, can still participate safely and effectively in exercise programs if proper monitoring of signs/symptoms and guidance on AE intensity are provided.

High-Intensity Interval Training

High-intensity interval training (HIIT), defined as repeated bouts of short-duration (ie, 10 seconds to 5 minutes) high-intensity aerobic exercise separated by brief periods of lower intensity aerobic exercise or rest, has gained some popularity in CAD and heart failure populations. The most common approach consists of a 10-minute warm-up followed by 4 × 4-minute intervals at 85% to 95% peak HR (or RPE 15-18), with active recovery periods of 3 minutes at <70% peak HR (RPE <13). The HIIT approach has been shown to result in greater cardiovascular effects than the more traditional continuous, moderate-intensity aerobic training but has not been sufficiently studied for widespread application.^{9,20} Further studies are required to adequately evaluate the feasibility, long-term effects, and safety of this approach. At this point in time, the HIIT approach should only be encouraged in stable CAD patients participating in medically supervised exercise programs.

Duration of Aerobic Exercise Training

The recommended duration of AE for CAD patients is similar to that for apparently healthy participants. Although 20 to 60 minutes of continuous AE is the standard recommendation for most CAD patients, recent guidelines² suggest that an accumulation of shorter exercise sessions throughout the day (ie, three 10-minute bouts) is comparable to a

single, continuous session. Both of these approaches provide an increase in energy expenditure and can lead to improvements in functional capacity as well as other physiological benefits.²¹ However, there is a need for more studies that directly compare the 2 training models (ie, continuous vs intermittent) in CAD patients before clear conclusions can be reached regarding comparable AE adaptations. Finally, the exercise professional must recognize that AE intensity and duration are generally inversely related; consequently, the standard recommendation is to have the patient start with a light to moderate AE intensity (ie, 40% to 60% of MHR or VO_2R) and increase duration until the desired level (30-40+ minutes) is attained before increasing intensity.^{1,2}

Frequency of Aerobic Exercise Training

The recommendation for AE frequency for primary prevention programs²—3 to 5 days per week—is also appropriate for secondary prevention in CAD patients. Most exercise programs offer 2 to 3 supervised exercise sessions per week and should also encourage their patients to be physically active—within prescribed limits—on most days of the week. The appropriate AE frequency for a given patient will depend on the individual's goals. Most CAD patients can achieve improvements in functional capacity (increased $\text{VO}_2\text{ max}$; decreased HR at given workload, reduced symptoms) with 2 to 3 AE sessions per week, provided that the intensity and duration of these sessions are adequate. However, patients in need of aggressive risk factor intervention (ie, to decrease obesity or hypertension, normalize blood lipids, improve glucose tolerance, etc) will likely benefit from a greater frequency of AE.² Increasing the number of sessions per week (to 4 or 5) will help modify these risk factors over time; however, health care professionals should recognize that there is a direct relationship between the frequency of AE and the risk of orthopedic injury.² Thus, patients must be instructed to slowly increase the AE frequency (and

duration) and be aware of signs/symptoms of overuse injuries. Alternating modes of AE (eg, cycling, walking, swimming) may help reduce risk of overuse injuries²² and reduce boredom.

Progression of Aerobic Exercise Training

As described, the general recommendation in CAD patients is to increase the AE duration and/or frequency *before* increasing the intensity. More specifically, patients should be able to achieve a duration of ≥20 to 30 minutes of continuous AE before increasing the intensity.² Because many CAD patients will begin AE with a significantly lower functional capacity, due to disease, inactivity, and/or medications, compared to their healthy counterparts, their rate of progression will likely be slower. In fact, as a consequence of extremely low functional capacity or limiting symptoms (ie, angina, claudication, dyspnea), some CAD patients may need the AE to be intermittent during the early stages. The goal is to gradually progress toward 15 to 20 minutes of continuous AE at the target intensity. However, patients limited by symptoms will continue to need a more conservative rate of progression and may never reach the desired duration.²

Prescribing Aerobic Exercise Based on Energy Expenditure

Accumulating evidence suggests that specific health outcomes, including cardiovascular morbidity and mortality, are directly related to the total “volume or dose” of physical activity, most accurately quantified in kcal/week.² Weekly energy expenditures exceeding 1000 kcal/week are more effective in modifying risk factors associated with obesity (hypertension, impaired glucose tolerance) and may also contribute to a slower progression of coronary disease. Hambrecht and colleagues²³ assessed the relationship between leisure-time physical activity and coronary artery progression in 62 CAD patients before and after a year of lifestyle intervention. Results showed an inverse dose-response relationship

between the amount of physical activity and the progression of CAD. Patients who reported >2200 kcal of activity per week were found to be more likely to have regression of their CAD lesions. This amount of energy expenditure equated to approximately 5 to 6 hours of physical activity per week. Patients who reported <1000 kcal/week were more likely to have progression of their CAD. The middle group of patients—those reporting an average of 1500 kcal/week—showed no progression (but no regression either) of CAD. It should be noted that the physical activity estimates in the study were derived from activity-recall instruments that rely on the patient's self-report of activity habits. Thus, there may be inaccuracies with these self-reported estimates (ie, precise number of kilocalories expended per week). More studies on this issue are needed before the definitive “dose” of physical activity associated with the regression of coronary artery (if any) can be identified. Nevertheless, the results of the Hambrecht et al²³ study suggest that a threshold of approximately ≥ 1500 kcal/week can slow disease progression in cardiac patients. Consequently, health care provided should encourage CAD patients to achieve a volume of physical activity that will meet/exceed these caloric thresholds. Unfortunately, several studies²⁴⁻²⁷ indicate that traditional cardiac rehabilitation exercise sessions usually result in <300 kcal/session. Thus, participating in 3 exercise sessions per week, without any additional lifestyle physical activity, will expend only 1000 kcal/week.²⁸ At this level of energy expenditure, CAD progression is likely to occur. Increasing the frequency and/or duration of AE as well as promoting more “lifestyle physical activity” would be the most effective way to increase the total energy expenditure. Low-moderate intensity lifestyle physical activity results in an energy expenditure of approximately 5 kcal/min, whereas moderate-high intensity AE expends ~ 7 kcal/min. Thus, in order to reach a target “volume” of 1500 kcal/week, the typical CAD patients would need to perform ~ 300 minutes of low-intensity physical activity per week.

Figure 2.

The physical activity pyramid.

Role of Aerobic Exercise Training for Weight Management

Coronary artery disease patient are certainly not immune to the “obesity epidemic,” and >80% of patients entering cardiac rehabilitation programs are overweight and >40% are obese.^{29,30} Accumulating evidence³¹ indicates that the amount of AE and/or physical activity required to sustain weight loss and prevent weight gain is considerably more than the general recommendation of 150 min/week. Overweight and obese individuals will benefit from progression to >300 min/week of AE (eg, ≥ 60 min/day, 5–6 times/week) or ≥ 2000 kcal/week. For some individuals, progression to 60 to 90 min/day of exercise/physical activity may be necessary to promote and/or maintain weight loss.³² As discussed earlier, performing just 3 AE sessions per week is unlikely to expend enough energy to reach these target levels. Thus, AE and/or lifestyle physical activity must be obtained outside of the tradition ExRx if these target levels are to be achieved. Current research suggests that “bouts” of AE, as little as 10 minutes and distributed throughout the day, can be an effective strategy for weight loss as long as the total volume (eg, “dose”) that is accumulated³³ achieve the

levels described earlier. Thus, in addition to structured bouts of exercise, an increase in lifestyle physical activity should also be encouraged for overweight/obese patients with an overall goal of constructing a physical activity “pyramid” (Figure 2). The health care provider must establish appropriate weight loss goals and convey to patients that a 5% to 10% reduction of body weight during a 3- to 6-month period is considered successful and likely to produce significant health benefits.³¹

Ades and colleagues²⁷ have demonstrated that a high-calorie-expenditure AE (3000–3500 kcal/week of exercise-related energy expenditure) compared with standard cardiac rehabilitation AE program (≤ 800 kcal/week) resulted in twice as much weight loss (Figure 3) and better cardiometabolic risk factor control, at 5 and 12 months, in overweight CAD patients. Furthermore, several studies have used physical activity monitors, such as pedometers and/or accelerometers, to help individuals achieve these higher volumes of physical activity^{34,35} and successfully lose weight.³⁶ As shown in Figure 4, we recently demonstrated that accumulating 6500 to 8500 steps/day appears to be an appropriate target level of physical

Figure 3.

The change in bodyweight (kg) for cardiac rehabilitation (CR) patients in standard (triangles) and high-calorie-expenditure CR program after 5 and 12 months.

Figure 4.

The relationship between levels of physical activity energy expenditure (PAEE in kcal/day) as well as minutes of moderate-vigorous physical activity (min/day) compared to steps/day.

activity for CAD patients as these levels are associated with approximately 1500 to 2200 kcal/week of energy expenditure.³⁷ As previously indicated, these levels of physical activity appear to be required for CAD stability/progression as well as weight loss in CAD patients.

Resistance Exercise Training

Since their inception in the 1970s, preventive and rehabilitative exercise programs for CAD patients have focused mainly on prescribing a safe and effective AE program. Despite initial

concerns regarding potential negative consequences on myocardial function, resistance exercise (RE) training has been shown to provide many important benefits for CAD patients in primary and secondary prevention programs.³ While the basic principles for prescribing RE apply to most stable CAD patients, the potential for complications should dictate who participates (ie, patient eligibility) and when (ie, time course following a cardiac event), as well as specific prescriptive guidelines.³⁸

Most CAD patients can participate in RE programs safely, as long as they receive instruction on appropriate lifting techniques and use loads appropriate for their capacity (eg, ~40% to 50% of 1 RM). In addition, CAD patients should be instructed to avoid the excessive isometric contraction associated with gripping too tightly and straining as this may cause a dramatic increase in BP. A well-rounded RE program should include 1 to 2 sets of 10 to 15 exercises that work the major muscle groups, with a training frequency of 2 to 3 times/week. The decision to initiate an RE program should be made by the health care provider in consultation with the cardiologist and/or surgeon. However, RE is generally contraindicated for CAD patients with the following clinical conditions²:

- Unstable angina
- Uncontrolled arrhythmias
- Left ventricular outflow obstruction
- Symptomatic heart failure
- Severe valvular disease
- Uncontrolled hypertension (ie, systolic BP ≥ 160 mm Hg; diastolic BP ≥ 105 mm Hg)

In addition to these clinical conditions, it is also advisable that CAD patients should have a normal or minimally reduced left ventricular function (EF $> 35\%$) and a functional capacity ≥ 5 METs before starting a RE regimen. In contrast, range of motion (ROM) exercises can be initiated soon after a cardiac event (ie, within 2 weeks) by incorporating very low intensity RE exercising using elastic bands, hand weights, and so on. While

these low-intensity RE activities can be started very early and for most CAD patients, the ACSM and AACVPR guidelines^{2,3} recommend the following for starting a traditional RE program (defined as lifting $\geq 50\%$ of his or her 1-repetition [RM] maximum):

- Post-MI and postsurgical patients should defer traditional RE for at least 5 weeks after their event/ surgery.
- Post-PCI (percutaneous coronary intervention = angioplasty, stent) patients should defer traditional RE for at least 2 to 3 weeks after the revascularization procedure.
- It is recommend that CAD patients complete a minimal period (ie, 2 weeks for post-PCI and 4 weeks for post-MI/surgery) of supervised CR endurance training before starting a traditional RE.

Special Considerations/ Modifications for Prescribing AE and/or RE

Myocardial Ischemia/Infarction

Although mode, duration, and frequency of the ExRx are similar to recommendations for other CAD patients, identifying the appropriate exercise intensity for ischemic or post-MI patients may be difficult when signs or symptoms arise. Myocardial ischemia is arrhythmogenic regardless of whether symptoms are present or not (ie, “silent” ischemia); thus, the target HR for exercise should be set ≥ 10 bpm below the ischemic ECG changes or angina threshold.² The following are recommendations for prescribing exercise for the patient with myocardial ischemia^{2,39}:

- Patients with angina should be instructed to recognize symptoms and avoid exercise interventions higher than level 2 (on 1-4 angina scale) during exercise, physical activity, or activities of daily living. Angina symptoms not relieved by cessation of exercise and/or the use of 3 sublingual nitroglycerin tablets (one every 5 minutes) require an emergent response.

- Exercise may be inappropriate for patients with angina and poor fitness levels or very low ischemic thresholds. However, non-weight-bearing exercise at very low levels may be appropriate to improve function.
- Exercise sessions should start with an extended warm-up and cool-down (10-20 minutes), which may decrease episodes of angina. The goal of the extended warm-up is to increase HRs ~ 10 to 15 bpm before engaging in more vigorous exercise.
- Upper-body aerobic or RE may evoke early-onset angina, and caution should be used when RE programs are initiated. Patients also need to be advised that any physical activity in cold weather may also exacerbate ischemic symptoms.

Surgical/Catheter-Based Revascularization

More than a million Americans undergo PCI or CABG revascularization procedures every year.⁴⁰ The majority of participants entering cardiac rehabilitation programs will have undergone one or more of these interventions.⁴¹ While the “traditional” ExRx described in this review is generally appropriate for the postsurgical/PCI patient, the following are some specific modifications that should be made for these patients^{2,42}:

- As there is often significant soft tissue and bone trauma to the thoracic cavity after CABG, ROM exercise should be undertaken in the early postsurgical period. ROM should be performed without feelings of pulling on the incision or mild pain.
- CABG patients that experience sternal movement or wound complications should not perform upper-body exercise or RE until healing is complete. As described earlier, the CABG patient should perform 3 to 4 weeks of AE exercise before initiating traditional RE.
- Asymptomatic PCI patients can begin RE after 2 weeks of AE.
- Walking is a highly recommended and beneficial mode of exercise that

can be initiated within a few days of the CABG or PCI procedure.

Implanted Pacemaker/ Defibrillator

The number of patients receiving implanted pacemakers and/or defibrillator continues to increase as does the complexity of the devices. Health care provided working with these patients should consider a recent evidence-based review⁴³ and develop a solid understanding of these devices (including the 4-letter code system used to describe the device functions) and their potential impact on exercise recommendations. The following is a brief list of specific recommendation/considerations for these patients^{2,44}:

- The device discharge thresholds must be known so that HR levels during exercise can be kept safely below this value (~ 10 -20 bpm) to prevent inappropriate shocks.
- RPEs should be used in conjunction with HR to regulate exercise intensity.
- Upper-body/shoulder motion should be limited initially to prevent dislodging of the leads, and traditional RT should not be performed until 4 to 6 weeks postimplantation.

Diabetes (Type 1 and Type 2)

Diabetes leads to a number of pathological complications that result from chronically elevated blood glucose and/or insulin concentrations. Specifically, individuals with diabetes may develop conditions such as retinopathy, nephropathy, end-stage renal disease, and complications associated with neuropathy, which have the potential to impact the ExRx. While a comprehensive overview of ExRx for individuals with diabetes is provided by the ADA and ACSM,^{2,45,46} a summary of recommendations from these organizations for prescribing exercise for the patient with diabetes is listed in the following:

- In addition to traditional HR/BP monitoring, pre- and post-blood glucose monitoring is recommended

during the initial weeks of the exercise program until glucose control has been established.

- The goal is to avoid postexercise hypoglycemia; thus, preexercise glucose levels should be ≥ 100 mg/dL. Low preexercise glucose levels should be increased with 20 to 30 g of carbohydrates before starting the exercise bout.
- Patient should not exercise if blood glucose levels are ≥ 300 mg/dL (or ≥ 250 mg/dL with the presence of urinary ketones).
- The primary goal for individuals with type 1 diabetes is to develop a consistent “pattern” of exercise, carbohydrate intake, and insulin dosing.
- During exercise, autonomic neuropathy may cause chronotropic incompetence and/or a blunted BP. Diabetics may also have difficulties with thermoregulation and dehydration and should avoid exercise in extreme hot/cold environments.
- Type 2 diabetics will benefit from participation in RE when contraindications such as retinopathy are not present. Emphasis must be placed on good technique to avoid straining and proper breathing to prevent the exaggerated BP responses associated with the Valsalva maneuver.
- Diabetics with peripheral neuropathy may need to avoid weight-bearing activity and regularly inspect their feet. Caution should be used for those with autonomic neuropathy while exercising in hot or cold environments.

Hypertension

The ACSM has published recommendations for exercise training of hypertensive individuals in a position stand⁴⁷ as well as within its Exercise Testing and Prescription Guidelines.² Hypertensive patients should be screened for contraindications to exercise and those with a resting BP $\geq 180/110$ mm Hg should be encouraged to see their physician for improved BP control

prior to beginning an exercise program. The following is a summary of the ACSM recommendations^{2,47} regarding the prescription of exercise in hypertensive patients:

- Consistent monitoring of pre- and postexercise BP is important during the initial stages of the exercise program, and hypertensive patients should perform an active cool-down to avoid the risk of postexercise hypotension.
- Aerobic exercise, performed at a lower intensity training (40% to 60% of VO_2R), has been showed to effectively lower BP in hypertensive individuals.² The lower intensity training may also facilitate increased duration and total energy expenditure in patients that are overweight or obese.
- Do not exercise if resting BP $\geq 200/110$ mm Hg. During exercise, BP should remain $\leq 220/105$ mm Hg.
- Patients with hypertension should be advised to avoid isometric hand gripping during all RE exercises to avoid a disproportionate increase in SBP. Proper breathing techniques during RE should be encouraged to avoid the Valsalva maneuvers.

Summary

This reviews presents the basics of ExRx principles pertaining to AE and RE programs in patients with CAD. While objective data from an exercise test are preferred for developing the ExRx, often the health care professional will have to rely on the more “subjective” or arbitrary techniques described. Consequently, prescribing AE and RE exercise for CAD patients is often “more of an art than a science.” This review also described the more contemporary perspective that there is an appropriate volume/dose of physical activity, regardless if the energy expended is from structured “exercise” or from lifestyle related activities, to promote CAD stability/regression and weight management in CAD patients. Finally, specific modifications to the standard ExRx were reviewed for some of the more common subgroups of CAD

patients. Despite the potential for untoward events, there is considerable evidence to suggest that properly prescribed and monitored exercise therapy is not only safe but highly beneficial in patients with CAD. Health care providers are encouraged to refer CAD patients to preventive/rehabilitative programs where these the principles of ExRx can be provided in a safe and effective environment. **AJLM**

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